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REPORT FOR MONTH ENDING NOVEMBER 27, 1943

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~~SECRET~~I. Abstract

The activities of this section previous to the start-up of the pile were, in the main, preparations for that event and do not require special mention. Exception to this statement may be made in regard to Mr. Jones' group who, in addition to testing all the graphite which went into the pile, ran an exponential pile with the X-lattice and built and calibrated a standardizing pile for determining neutron fluxes and slowing down densities by means of indium foils. A separate report will appear on the latter development.

The pile was built as a graphite honey comb without any uranium until all mechanical and electrical features had been installed and tested. The metal was loaded by means of charging holes through one side of the shield. The introduction of the metal into the pile required only about twelve hours. The rise of the neutron density at the center of the structure was observed continuously with a boron trifluoride counter and in addition the loading process was interrupted from time to time in order to activate an indium foil. These intervals were so spaced that the shape of the pile was approximately cylindrical at each interruption of the loading. Both the counts of the boron trifluoride counter and the activities of the indium foils were plotted and an attempt was made to extrapolate these plots to predict the critical loading. Two forms of the extrapolation were used, both of which predicted that the critical loading was about 360 filled channels. Loading was actually stopped at 369 loaded channels and it appeared that the actual critical loading was 362.

After the chain reacting condition had been reached the reactivity of the pile was about 28 inhours. At Mr. Fermi's suggestion twenty more channels were loaded for the purpose of determining the relation between the period and k . The constant connecting the change in k with inhours was 3×10^{-5} .

One of the power experiments also gave a temperature coefficient for increasing the temperature of the metal alone. This was .8 inhours per degree centigrade for the temperature of the particular slug measured. Estimating the corresponding temperature of the central slug one arrives at a coefficient of .6 inhours per degree. A second temperature coefficient experiment was made by heating the whole pile uniformly by means of radiators at the air intake of the air cooling system. This gave a coefficient of .73 inhours per degree. The fact that the metal temperature apparently accounts for most of this effect is rather surprising. Other inexact data taken during actual operation of the pile indicate a larger effect due to graphite and a correspondingly smaller effect due to metal. Further work will be done on this point when more thermocouples are installed in the pile and better temperature data can be taken.

A test of the γ shield was made. No detectable neutron intensity was found at the outside of the full shield. The small gamma-ray intensity was well below tolerance at γ levels.

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After the preliminary experiments were completed the pile was put into full power operation with the maximum metal temperature of about 100° C. This is as great a temperature as seems safe at the moment. The power output under these conditions varies between 300 and 500 kw depending on the outside air temperature. The change in average air temperature is very small because of the large number of unfilled channels which allow two-thirds of the air to pass through without being heated appreciably.

Henry W. Newson
Henry W. Newson

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II. Monitoring and Loading of the Pile

The various measurements described here were made by the Physics Section and the pile operating group as a joint enterprise. Most of the section took part in the measurements described and little attempt has been made to acknowledge the contribution of the various individuals. Messrs. Fermi, Neil, and Feld were also present during most of the work and gave us the benefit of their previous experience on the Argonne pile. Many of the experiments were suggested and directed by these men.

The pile was completed and all of the subsidiary apparatus installed before any metal was loaded. The loading was carried out by pushing ^{metal} graphite slugs about four inches long and 1.1 inches in diameter into the channels in the pile. The channels were diamond shaped holes 1-3/4 inches on a side and were spaced 8 inches on centers in a square array. Figure #1 shows symmetrically the arrangement of the channels. A channel, which is at present filled, is shown by a number, and a channel now empty is shown by a dot. The columns are numbered from one to thirty-five from the left-hand corner, and the rows are numbered from fifty-one to eighty-six from the upper left-hand corner. A channel is specified by the number of the ^{row} ~~row~~ followed by the number of the column. Thus, the channels marked are 1367 and 2367. The centers of the channels are six inches from the outer surface of the graphite on all sides. The actual metal lying in the bottom of the channel is slightly nearer to the bottom of the surface and farther from the top surface. In the channels marked by numbers in figure #1 all metal loaded at the same time is indicated by the same number, except for three exceptions. A roughly circular section in the center of the loading is marked #1. This was the first batch of metal loaded. The channels marked Th were loaded with thirty pieces of thorium carbonate approximately identical in size with the metal slug, and the channel marked D was loaded with the short length of uranium pipe, which is to serve as a fast neutron bombardment chamber.

During loading the growth of the neutron activity in the pile was monitored continually with the BF₃ counter. The loading was also interrupted from time to time and an Indium foil activated. The data so obtained was extrapolated under suitable plot to predict the loading which would start the chain reaction. The formula used, $R^2/\text{Intensity} = \text{Const.} \times (1 - R^2/R_c^2)$ where R is the effective radius of a cylinder. R was calculated by multiplying the area of the cell (that is 64 square inches) by the number of channels loaded, and calculating the radius of a circle of equal area. To this was added about 42-1/2 cm for the reflector composed of the dead graphite outside the loaded channels.

In Table I the effect of the various loadings of the pile is shown. Indium foils were measured in two positions and one BF₃ counter was also used. However, activity of the Indium foil nearest the center is used in the table. Equally satisfactory results were obtained with the other Indium foil and the BF₃ counter. After each set of slugs was loaded the loading was stopped for a long enough time to activate an Indium foil to a convenient intensity. The

Table I

Order Number of Filling	Filled Channels	$A_s(\text{In})$ c/min	R^2 $\times 10^{-4}$	$\frac{R^2}{A_s}$	$\frac{R^2/A}{1 - \frac{R^2}{R_c}}$	$-\Delta \times 10^{-6}$ cm^{-2}	\bar{T} Dec.	ih
1	177	620	3.75	60.5	136	17347		
2	235	1180	4.72	40.0	132	14181		
3	297	2918	5.74	19.7	130	12003		
4	329	6344	6.26	9.8	133	11168		
5	341	10558	6.47	6.1	136	10884		
6	351					10663		
		(360) (Critical position as extrapolated from 10480 above.)						
		(361.7) (Critical position as extrapolated from 10447 below.)						
7	369					10306	904	26.5
		Small absorber in pile					126	23
8	373					10230	62	39
9	377					10156	35.5	56
10	381					10083	22.1	74
11	385					10012	16.7	86
12	389					9942	11.9	100.8
		One shim rod inserted						
	339							.29
13	399						111	25.6
14	429						18.7	81
		absorber removed						84.5
15	449 *	Small ionization chamber in pile Th and Bi also inserted					40.5	51.0
16	458						21.9	74.4
		Small ionization chamber removed						77.3

first column in Table I shows the number which is used to designate the loaded channel in Figure 1. The second column gives the total number of channels loaded up to this point. Numbers marked with an asterisk indicate that the last set loaded was not a full channel of 65 slugs, but a short channel of only 30 slugs which were loaded in the center of the pile so as to form a "pedestal" underneath the large hole where the W shield was measured. The third column shows the saturated intensity of an Indium foil very near the center of the pile. The fourth column gives the square of the effective radius; and the sixth column gives the expression which should be a constant by the above equation.

It will be seen that this condition was met very satisfactorily. The critical loading predicted by this extrapolation was 360 filled channels. After the pile was loaded beyond the critical position twenty channels were loaded, four at a time, and the period of the pile measured after each loading. These were shown as 8, 9, 10, 11, and 12 in Figure 1. From the value of the change of in-hours with the number of channels loaded it was possible to extrapolate back to the critical loading from this direction. This gave a result of 361.7 in good agreement with the value predicted by the Indium foils. From the change in the Laplacian with the increase in period, one may calculate the relation between the value of the reactivity of the pile in inhours and k . If one assumes a migration area of 630 sq. cm $S_K = 3.0 \times 10^{-5} S(\text{ih})$. This figure is subject to correction if a more accurate value of the migration area may be obtained. There is also a question whether the reflector allowance of 42.5 cm is correct for when the graphite is filled with holes, as in this case. An attempt will be made to determine this figure more accurately.

The critical value of the Laplacian from Table I is about 105×10^{-6} . This is to be compared with the value 95×10^{-6} resulting from the measurements of the exponential pile, using the A-lattice.

After set #12 of rods had been loaded a shim rod was introduced into the pile very close to the critical position and the pedestal was started. This consisted of 40 short uranium rods and reduced the reflector for the W shield experiment to 58 cm. The shield experiment was completed before any further loading. After the completion of this experiment the pedestal was built up to the top of the pile to give as great an intensity as possible for other experiments planned in this position. At the same time the two rows were filled with thorium and four full channels not shown on Figure 1 were filled with bismuth slugs of the same size as the uranium slugs. These holes are grouped in a square array about hole #1268. The effect of the bismuth had been previously measured and was known to be 3 inhours. The same measurements showed the effect of the thorium to be 50 inhours. The net loss of inserting all these materials was 30 inhours, which indicates that the gain due to the last top 20 channels in the pedestal was 23 inhours. To bring the reactivity up to the previous level nine more full stringers were divided. The total reactivity of the pile is then 178 inhours, which, added to the 53 inhours lost by the thorium and the bismuth, gives a total reactivity of 231 inhours.

After the pile had operated about a week some material from the hottest section was removed. When this was replaced, hole #186A was left vacant and the control rods placed in the critical position. Hole #186A was then filled and the period measured with the same setting. This resulted in an increase of 23.6 in hours. As nearly as can be ascertained, this channel is the most active in the pile.

III. Measurement of W-Shield

L. B. Borst

Measurements were made on November 8th and 9th on a six foot square sample of the iron-masonite shield to be used at W. This consists of a thermal shield 10" thick and six biological layers of 4-1/4" masonite and 3-3/4" iron. A reflector thickness of 56 cm was used. This thickness gives a more severe test than will be imposed at W. The sample was placed in the large hole in the upper shield. As it was erected, gold foils were placed in order to obtain as complete a picture of the neutron distribution as possible.

The first measurements were made using the thermal and three layers of biological shield. This permitted final performance tests on the instruments before great sensitivity and high pile intensities were required. The methods used for measurement were:

1. BF_3 counter shielded on back and sides with two feet of paraffin.
2. Indium foils shielded on back and sides with two feet of paraffin.
3. A differential (fast) neutron chamber shielded with two feet of paraffin.
4. A γ -ray counter shielded by 7" of Pb and two feet of paraffin.
5. An ion chamber measuring the sum of neutrons and gammas shielded with 5" of Pb and two feet of paraffin.
6. Gold foils buried within the sample.

A summary of results is given based upon the assumption that, because of differences in pile size, etc., 150,000 kw at X is equivalent to 250,000 kw at W. The values are stated for W conditions.

Method	:	Thermal + 3 biological layers:	Thermal + 6 biological layers
1	:	2.3×10^4 n/cm ² /sec	: 10 n/cm ² /sec
2	:	1.9×10^4 n/cm ² /sec	: 100 n/cm ² /sec
3	:	10^4 fast n/cm ² /sec	: 30 fast n/cm ² /sec
4	:	4.5×10^{-3} rr/hr	: 15 mr/hr
5	:	10^4 mr/hr	: 6 mr/hr

Tolerance is usually considered to be 200 n/cm²/sec and 12 mr/hr.

The distribution functions shown by the gold foils is of considerable interest. Foils were measurably active only through the thermal and first three layers of biological shield. In this interval the thermal neutron density fell by a factor of 3×10^8 , indicating that this amount of shield should be sufficient.

Foils at the iron-masonite interfaces show pure exponential behavior with a range of 4.8 cm. Measurements within the thermal shield show negative deviation from this curve.

The transverse distributions are plotted and show understandable behavior. The presence of an appreciable concentration of neutrons in the concrete surrounding the sample is observed at the beginning of the third biological layer. The leakage is still from the sample into the concrete at the beginning of the fourth biological layer (as determined by BF_3 counter measurements).

No neutron effects were observed which could be distinguished from instrument backgrounds. Reasonably observable effects was assumed and the upper limits calculated from them. Considering the manner in which the thermal neutrons are dropping off, as measured by gold foils, it seems probable that leakage from the concrete shield and through the back shielding would determine the radiation level at the upper surface of the complete shield sample. The gamma radiation through the full shield was measurable. Again this radiation may represent leakage into the instruments rather than radiations penetrating the full shield.

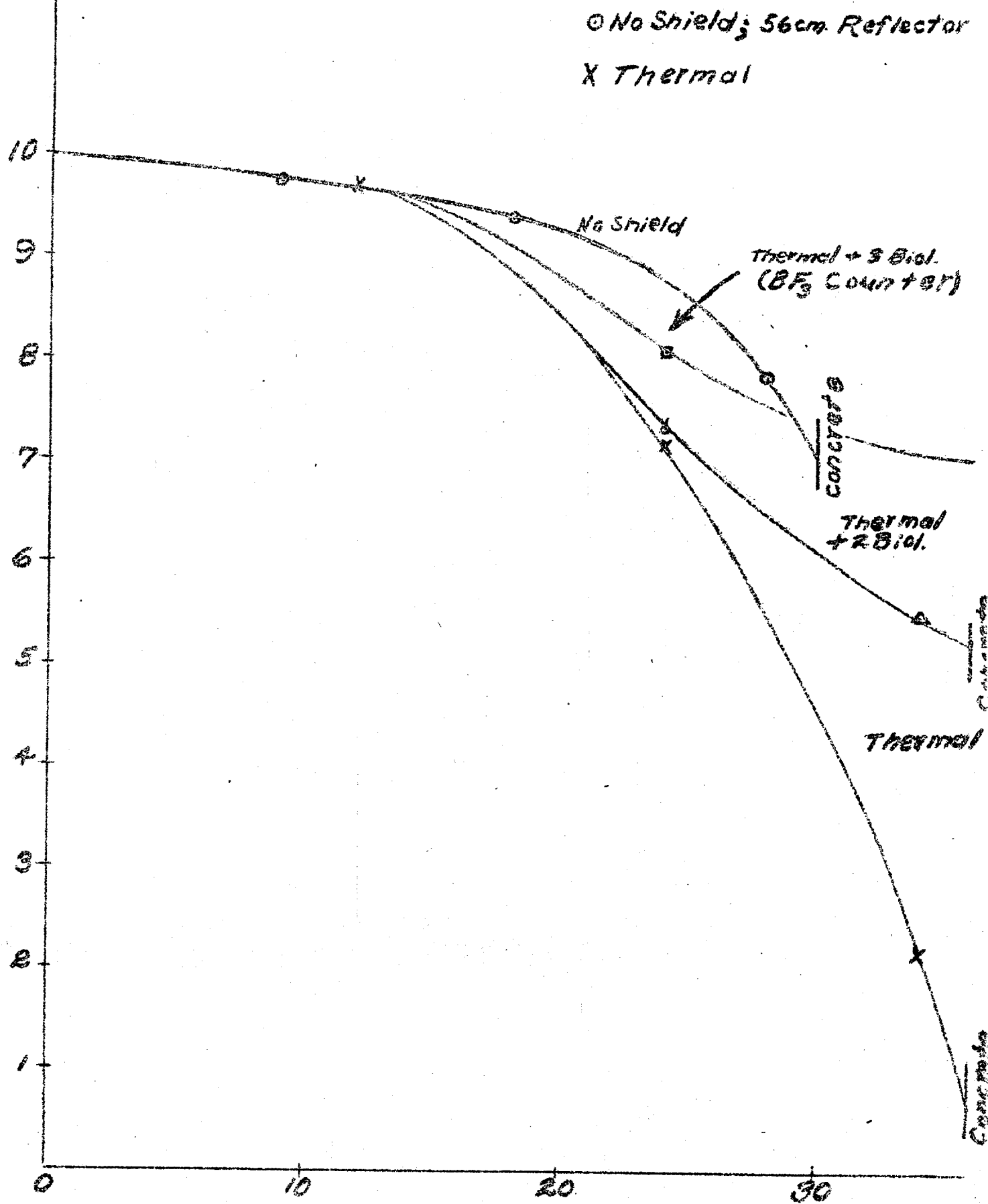
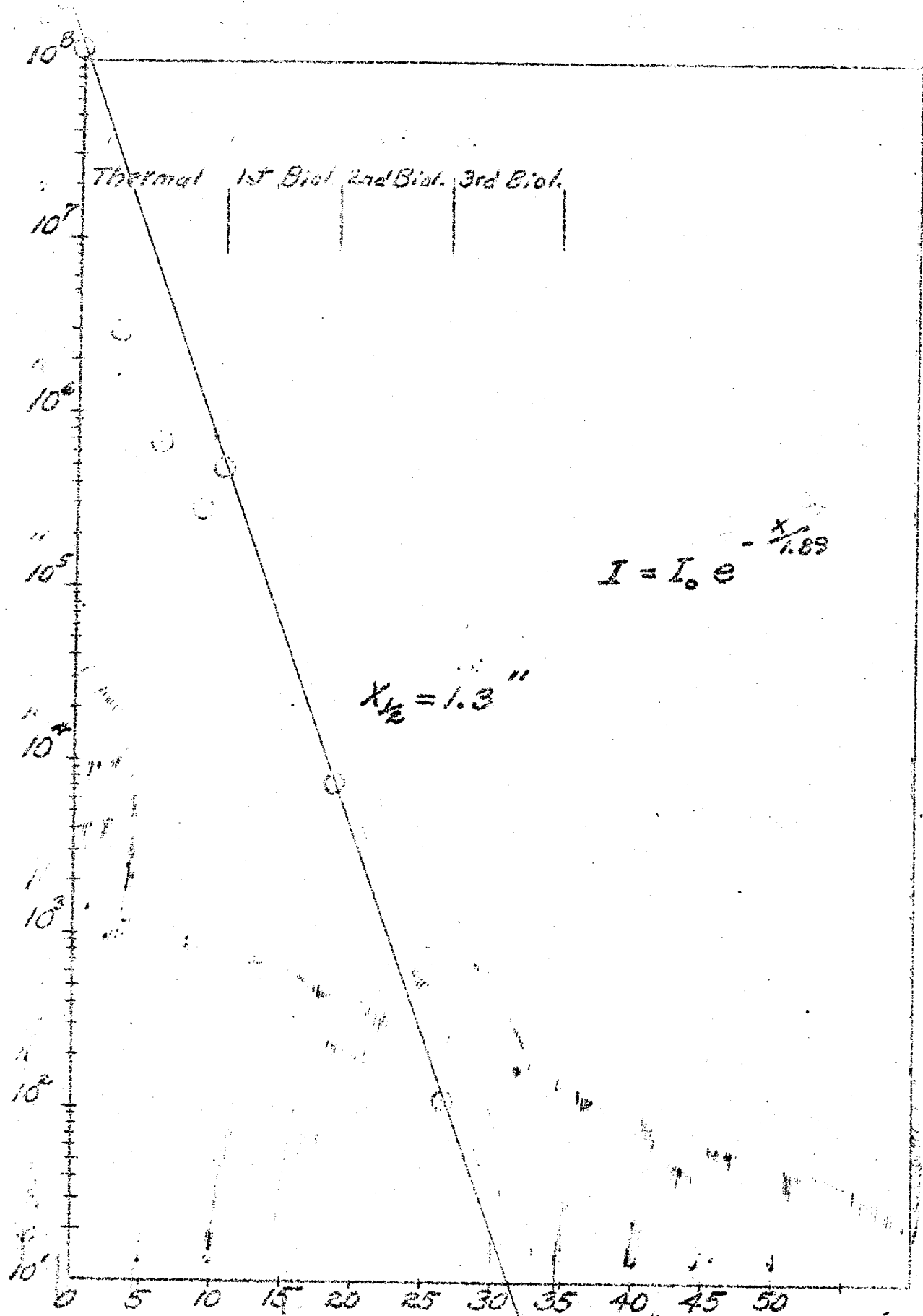


Figure 2.



Thickness in inches

Figure 3

IV. Temperature Measurements
(W. Kanne, M. Wilkening, R. McCord)

Twenty iron-constantan thermocouples were placed in the pile at start-up. Twelve of these measure graphite temperatures and eight measure metal temperatures. One of those in graphite has not been read due to physical inconvenience and one of those in the metal failed by shortcircuiting. The couples in the graphite were cast into 1/2" x 1/2" bismuth cylinders in an undercut hole in the graphite. Removable foil slot stringers were chosen for the location of these couples. The couples measuring metal temperatures are attached in two ways. Four of the couples are very nearly in the center of slugs. A tapered aluminum well extends axially two inches into the slug. The couple itself is pierced into a small tapered aluminum plug which is driven into the taper of the well. The other four couples are soft soldered to the outside of the aluminum jacket. The thermocouple wires are notched so that diameter of the conductor is about one half of its original value so that the wires break when the metal is discharged and can be recovered.

A brief description of the location of the various couples will be given in order that the temperature data can be interpreted. Due to removable core of the pile whose cross section is a square, two feet on an edge, and which runs the length of pile axially, no stringer can extend through the central axis of the pile.

The foil slot stringers are numbered 50 to 61 and are spaced on a nine point square array with a six foot spacing, when looking at one of the sides of the pile. The numbers from the north side range from 50 to 58 and increase in the direction of air flow and also from top to bottom. Then 53, 54, and 55 do not continue through the pile because of the removable core; 59 is the extension of 53 on the south side, 60 of 54, and 61 of 55. Thermocouples are located in the center of stringers 50, 51, 52, 56, 57 and 58, and 1-1/2 feet from the center of the pile in 53, 54, and 55. In stringer 54 there are two additional couples to give radial distribution data at distances of 5 feet (in block 4) and 8-1/2 feet from the center of the pile (in block 3).

Metal temperatures were measured at various points in order to get as much information about axial and radial distributions, temperature differences between metal and graphite in the same region and the difference in the indication given by the welded and soldered types of thermocouple attachment. The present locations may be identified as follows:

1860-31-S (later changed to 1865-29-S)
1868-32-S
1868-31-W
1869-46-W
1869-19-W
1869-20-S
2169-31-W
2169-32-S.

Since the vertical columns of the matrix formed by the charging holes are numbered 1 to 37 and the horizontal rows are numbered 51 to 87, each hole can be identified by giving its column number and row number. Thus 1860 is the hole at the intersection of column 18 and row 60. The numbers 31, etc., give the number of the slug from the discharge face, i.e. slug 1860-31-S is the 31st slug charged into hole 1860, and S signifies that the couple is soldered to the slug rather than inserted into a well (W).

Couple 1860-31-S is near the graphite temperature couple in stringer 51 and couples 2169-31-W and 2169-32-S are near the graphite couple in stringer 54 that is 1-1/2 feet from the center of the pile.

The results indicate that the soldered couples read about 5° C lower than those in wells. The solder melts at 183° C so that this type of couple is useful for measuring temperatures below about 150° C. and very easy to prepare. The welled type of couple will continue to be used in locations where temperatures above 150° C are anticipated.

In addition to the couples located at fixed points in the pile a number of traverses in foil slot and experimental holes have been taken. Figures 7, 8 and 9 show graphite temperatures taken at times that copper foil activations were made for the purpose of relating temperature and neutron intensity distributions. Figures 10, 11, and 12 show graphite temperatures taken for the purpose of determining the thermal conductivity of the pile in various directions. Figures 13 and 14 show radial and longitudinal metal temperature distributions. These data are preliminary and are presented at the present time without interpretation.

11-14-43 M.W.

-14-

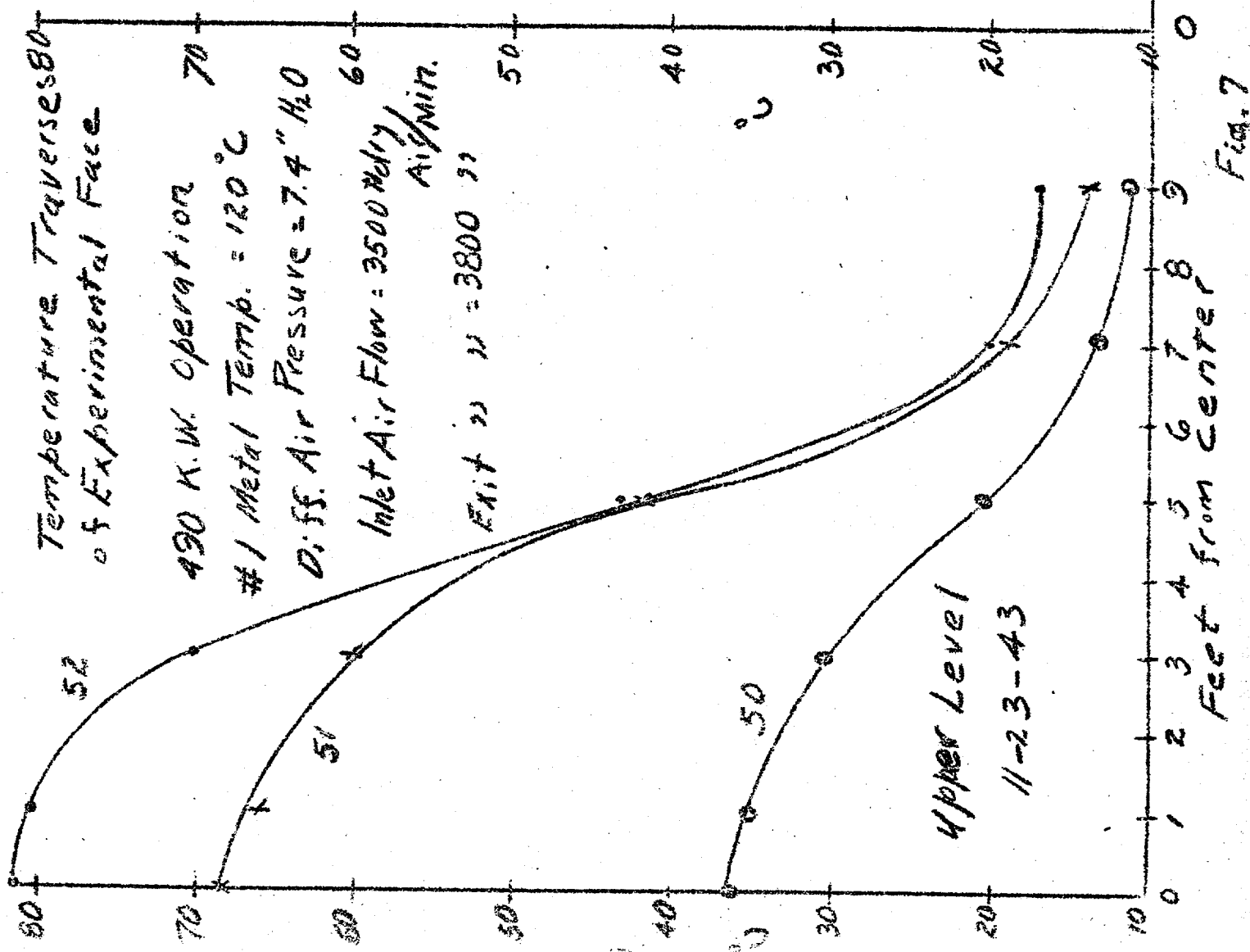


Fig. 7

Temperature Transverse 11/15/43

Experimental Face - Lower Level

58 ~ 100 min. after shutdown

57 ~ 120 min. " "

56 ~ 140 min. " "

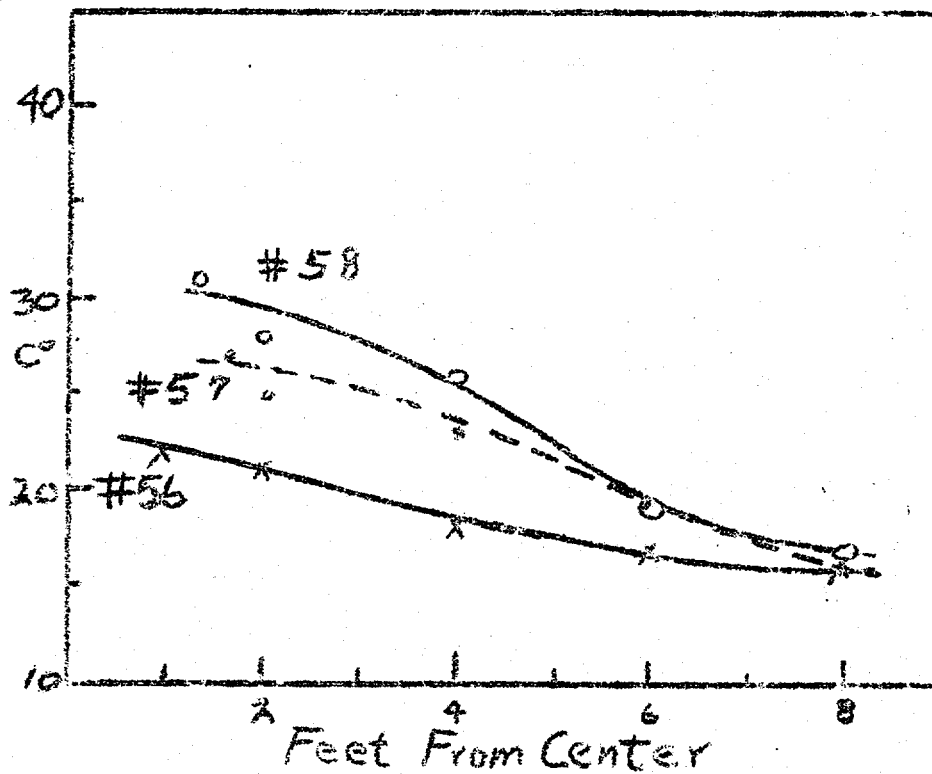


Fig. 8

Temperature Transverse - Charging Face

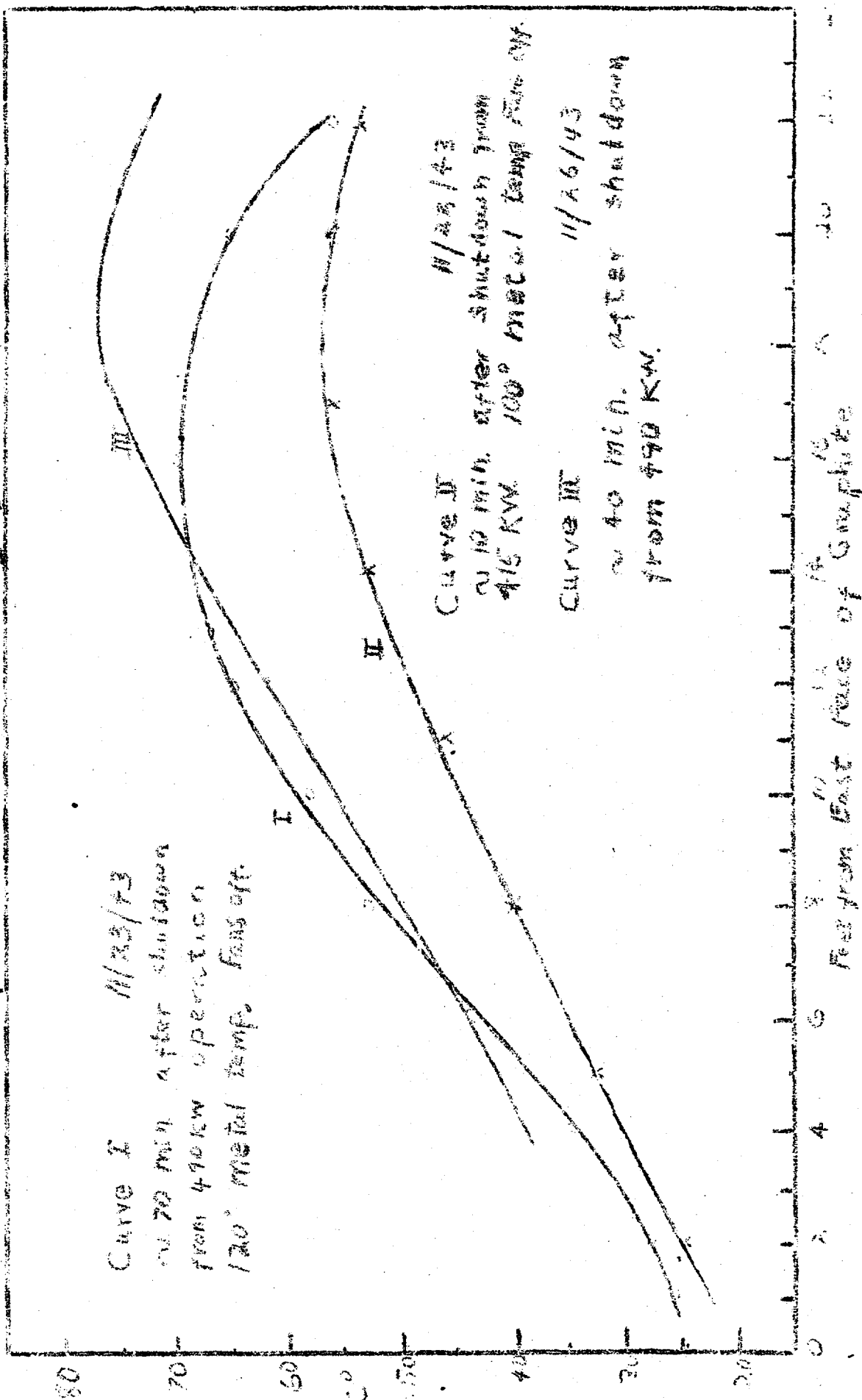
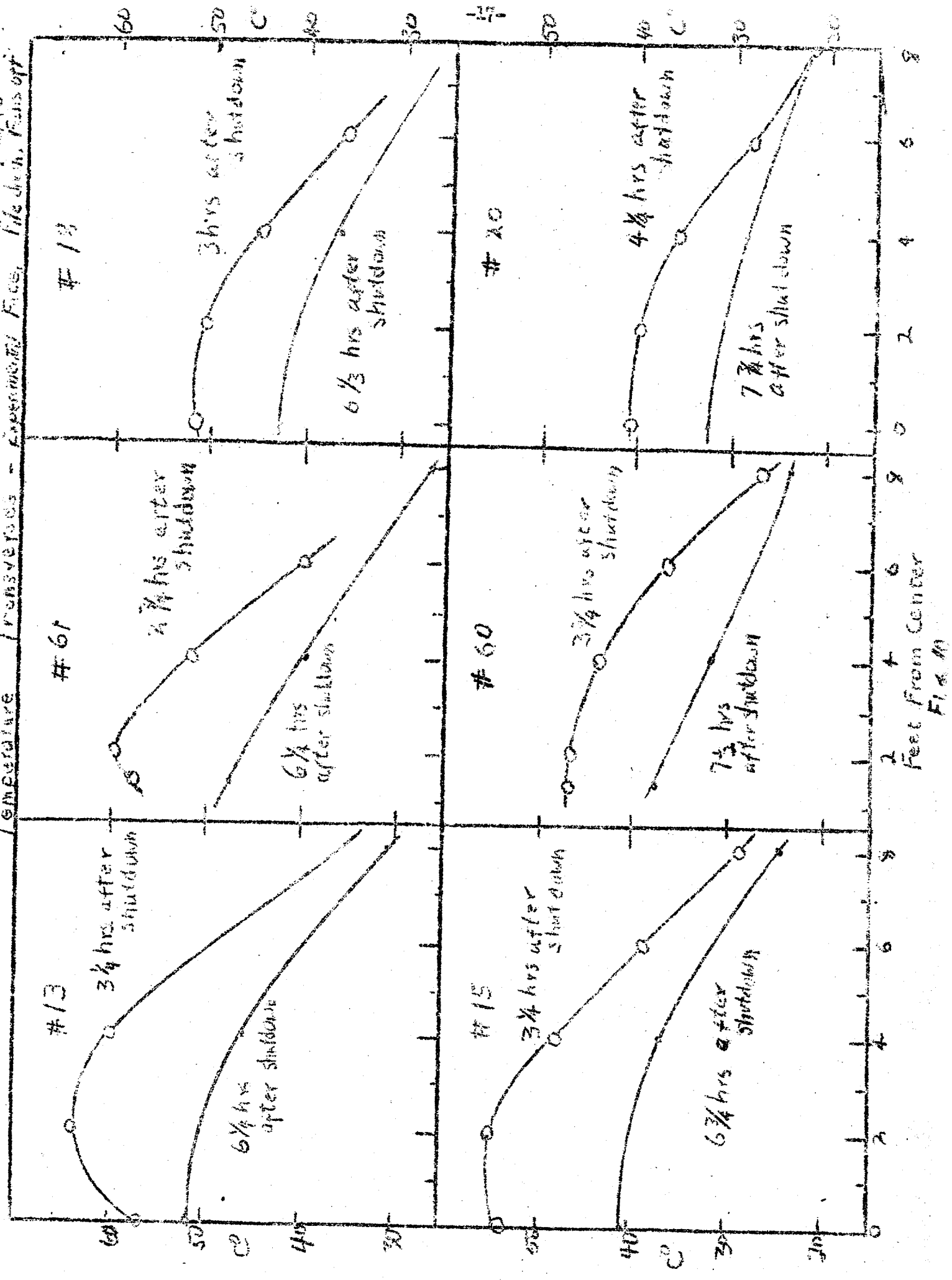


Fig. 9

11/24/43



Temperature Transverse - Hole 54-60 11/23/43

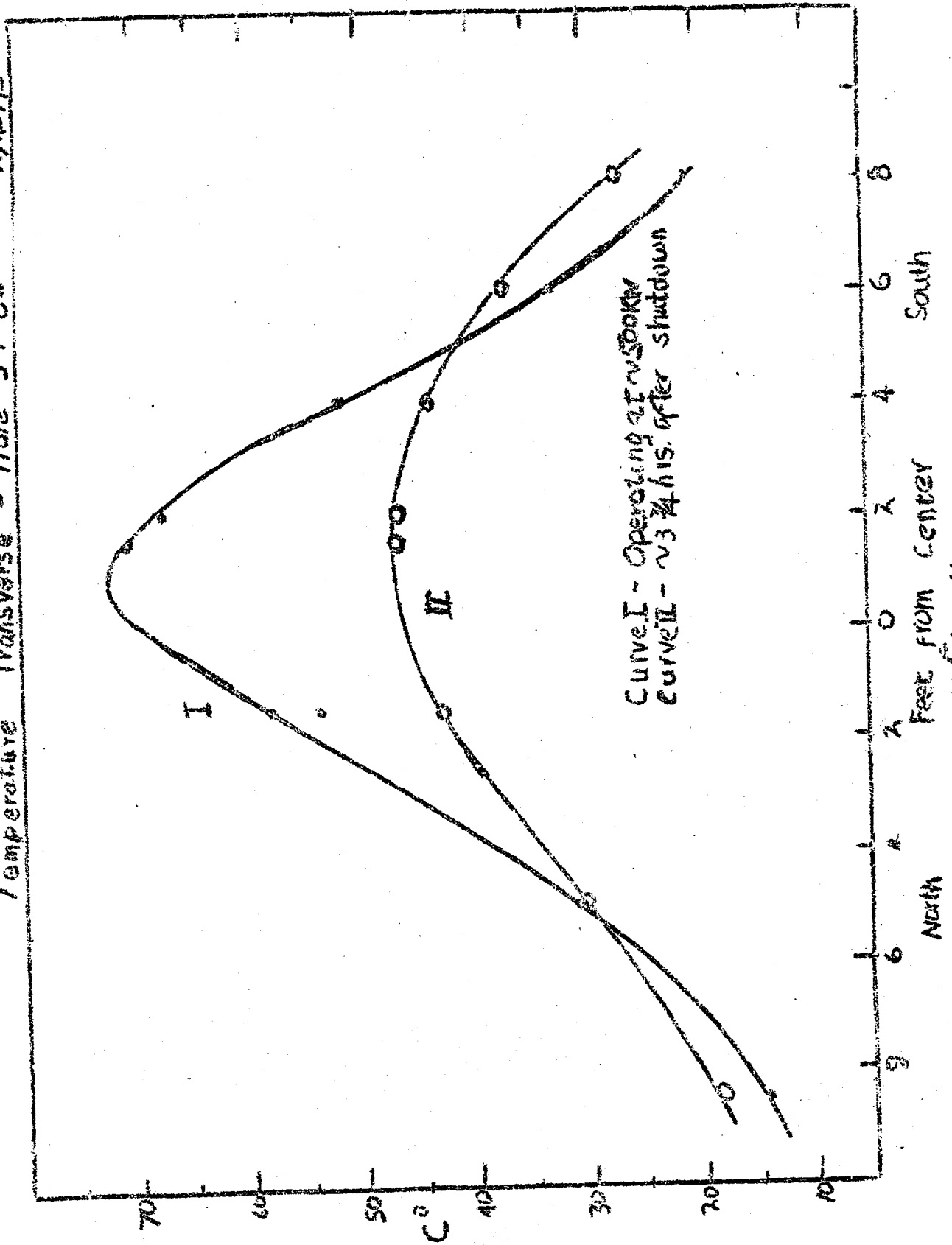
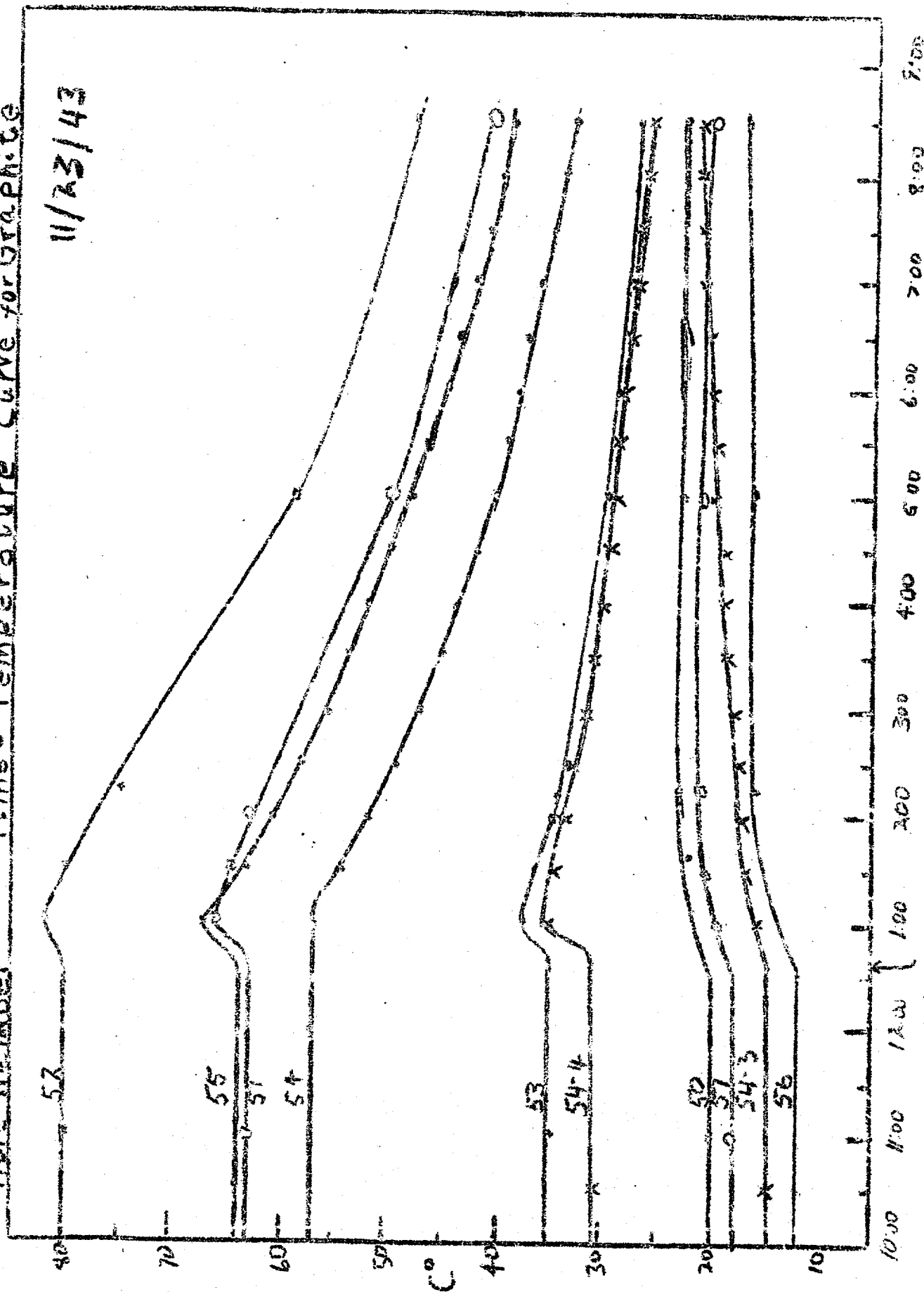


Fig. 11

Time - Temperature Curve for Graphite

11/23/43



Time
Fig. 12

File down

Longitudinal Metal Temperature Distribution

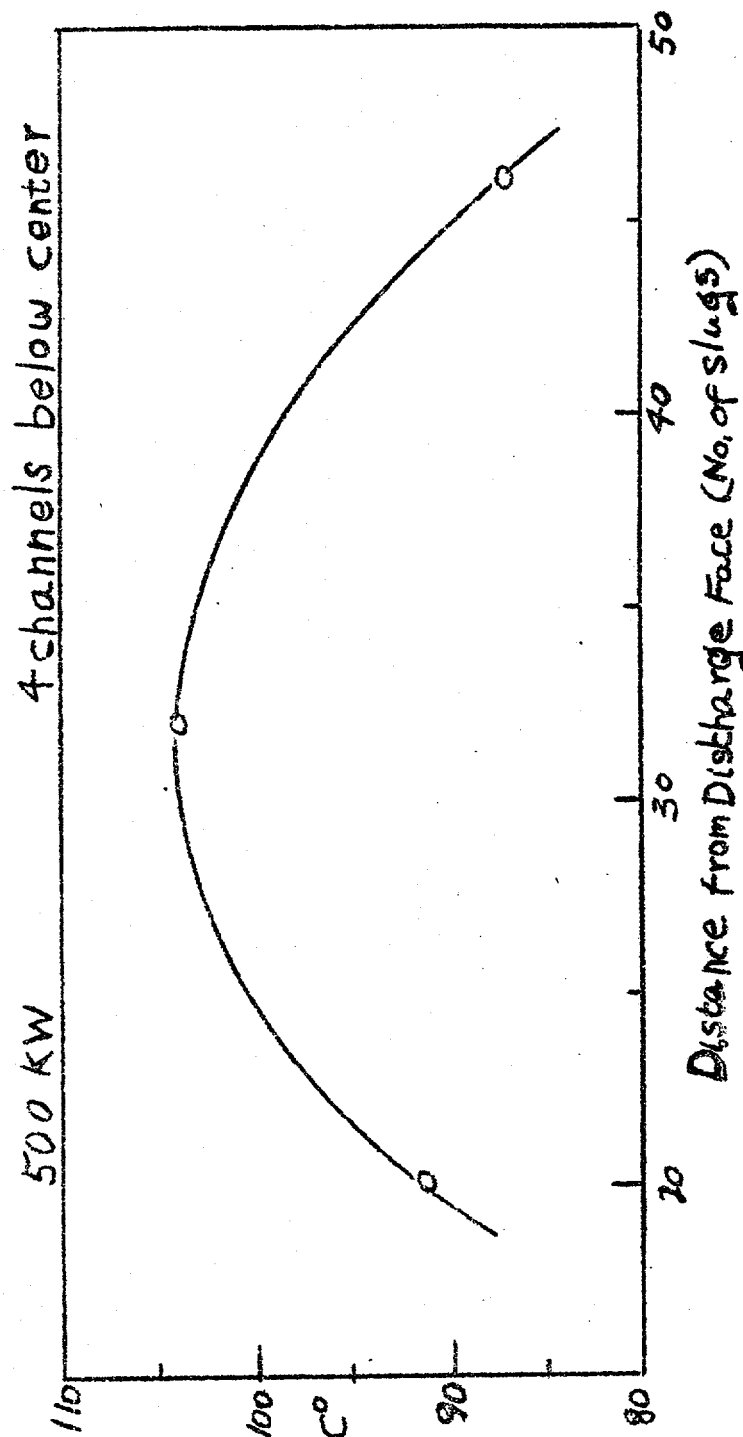


Fig. 14

Radial Metal Temperature Distribution

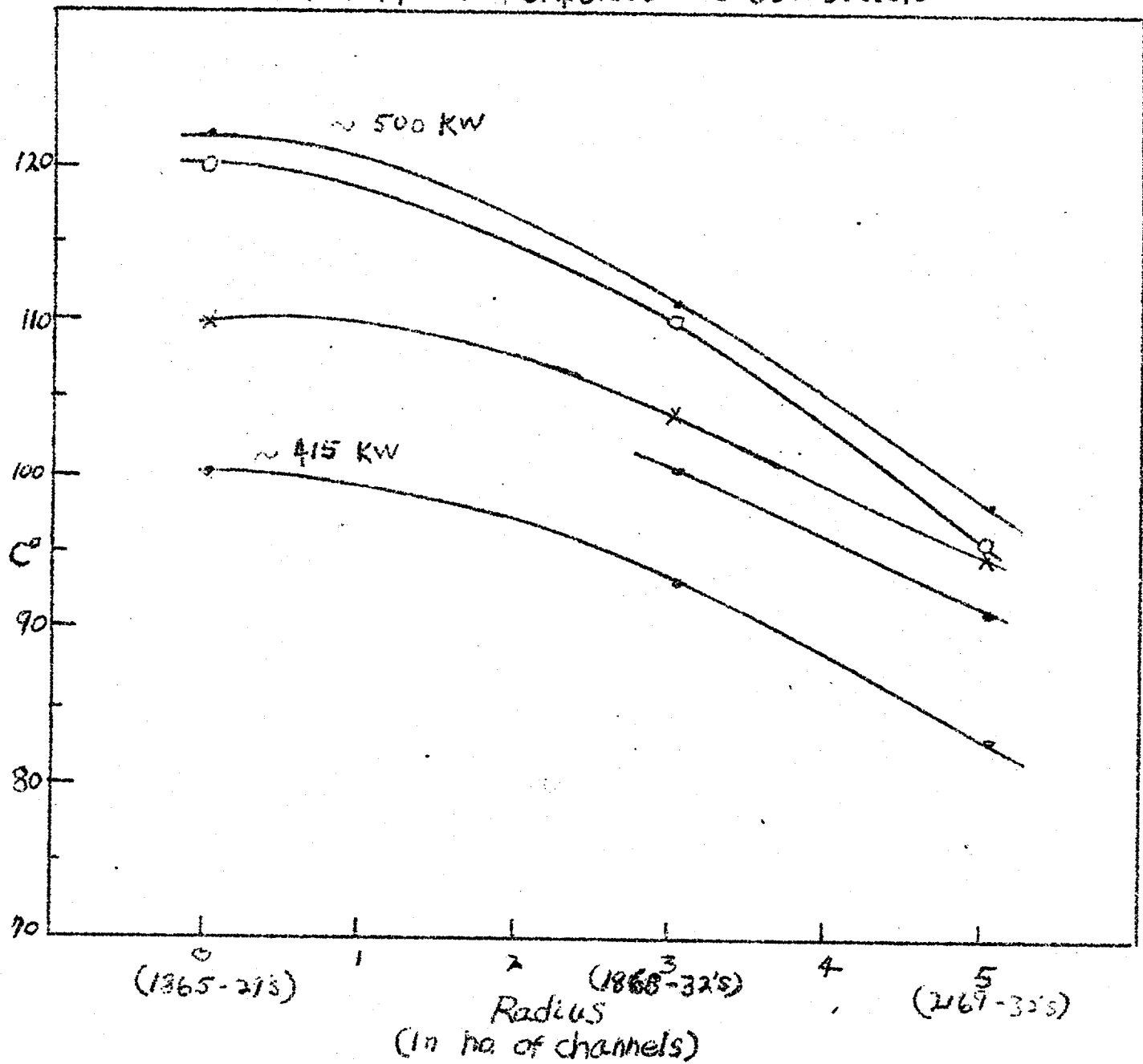


Fig. 13.

V. Calibrations of Control Rods

The various regulating, shim, and safety rods were tested on November 4th in order to obtain rough value for the effect on k possessed by each rod. The test consisted in inserting each rod separately into the pile and observing the rate of the BF_3 counter in the position that it had occupied during the previous night's period of metal charging. The relationship between the counting rate and the number of channels filled had been observed at that time. Thus it is possible to say that a rod reduced the reactivity of the pile to a condition equivalent to a loading of a certain number of channels. It was observed later that each channel loaded beyond the critical condition increased the reactivity by 4 inhours. This value was fairly constant and it was assumed that each channel below the critical condition also accounted for 4 inhours of reactivity. In the second column is given the number of loaded channels giving the same counting rate as was obtained with the pile with 365 channels loaded and the various rods introduced. The third column gives the inhours which each rod is capable of counteracting, and the fourth column gives the effect on k in percent, assuming that 1 inhour is equivalent to a change in k of 2.95×10^{-5} .

I	II	III	IV
Rod	Equivalent	Inhours	% k
Number	Channels Loaded		
1	326	156	.46
2	359	24	.07
3	311	216	.64
4	310	220	.65
5	342	92	.27
6	343	88	.26
7	350	60	.18
8	338	108	.32
9	348	68	.20

Rods #1 and #2 are regulating rods. Rods #3, #4, #5, and #6 are shim rods. All six of these rods are identical in physical properties and their different effects are due to their distances from the center loading of the pile. The actual locations of the rods can be seen on figure 5. Rods #7, #8, and #9 are safety rods which drop in from the top of the pile.

Control rod #1 was generally used during the start-up. It was calibrated roughly by measuring periods due to three displacements of the rod. It is hoped in a short time to calibrate this rod and also control rod #2 much more extensively. The shim rods will also be calibrated.

During start-up it was impossible to keep the pile under exactly the same

conditions for a sufficient length of time to measure barometric coefficient. A few observations were obtained indicating a coefficient about .4 or about .5 ih/mm. However, because of the sparse data, it seems best to use tentatively the Argonne figure of .32 ih/mm.

VI. Temperature Coefficient and Power Calibration

At Mr. Fermi's suggestion and under his direction an experiment was performed on the power output and temperature coefficient by raising the temperature of one of the slugs about 7° by running the pile. This experiment was performed with the cooling fans shut off. The following is quoted in Fermi's words.

"The energy output of the pile was calibrated by determining the temperature rise of one of the metal slugs above the temperature of the surrounding graphite during an operation of the pile for which the intensity was followed by observation of the readings of galvanometer #1 and of the Micronax recorder.

"The experiments started at 6:20 P.M. and the intensity of the pile was allowed to rise for a period of about 58.5 seconds until the galvanometer reading reached a peak of 26,000 cm deflection. The intensity was lowered to such a level that the temperature difference between the slug and the graphite was kept approximately constant for about twenty minutes. At 6:44 P.M. the intensity was rapidly dropped to zero and the temperature was followed for about ten more minutes.

"The temperature was recorded by a thermocouple inserted with one junction in the slug and one junction in the graphite near the slug. Mr. Kanne calibrated the thermocouple and obtained the temperature readings given in the second column of Table I at the time indicated in the first column.

"This relaxation time can be determined from the temperature readings taken from 6:44 P.M. to 6:54 P.M. The decrement of the temperature in this interval in which the power output of the pile was negligible fits an exponential decay constant of 4.78 minutes.

"If the slug were thoroughly insulated the amount of heat received by the slug would be calculated by multiplying its thermal capacity by the temperature rise, since the thermal capacity of the graphite is so large that its temperature remains virtually constant during the experiment. Since, however, the slug loses heat by conduction to the graphite, the actual amount of heat developed inside it by the process is larger. Indeed, the rate rise of temperature is given by the equation:

$$\frac{dT}{dt} = \frac{1}{c} q - \frac{1}{\tau} T \quad (1)$$

"where c is the thermal capacity of the slug, q is the amount of heat produced into it by per unit time, and τ is the exponential relaxation time (τ equals 4.78 minutes). From (1) follows:

$$\frac{1}{c} \int q dt = T + \frac{1}{\tau} \int T dt \quad (2)$$

"The values of the left hand side of this equation are given in column three of Table I. The figures in this column give the temperature rise that would have been observed in the slug if there had been no leakage of heat from it into the graphite. Such temperature rises multiplied by the thermal capacity of the slug

Table I of E. Fermi Report

t	T	$T + \frac{\int T dt}{4.78}$
6.20 P.M.	0	0
6:21	.07	.08
6:22	.24	.29
6:23	.64	.77
6:24	1.72	2.07
6:25	4.60	5.54
6:25 1/2	6.68	8.21
6:26	6.40	8.61
6:27	5.84	9.33
6:28	5.47	10.14
6:29	5.88	11.74
6:30	6.51	13.67
6:31	6.49	15.01
6:32	6.46	16.33
6:33	6.34	17.55
6:34	6.20	18.72
6:35	6.06	19.87
6:36	5.88	20.93
6:37	5.72	21.99
6:38	5.62	23.07
6:39	5.50	24.12
6:40	5.39	25.14
6:41	5.28	26.15
6:42	5.20	27.17
6:43	5.12	28.20
6:44	5.10	29.22
6:45	4.28	29.38
6:46	3.45	29.36
6:47	2.74	29.30
6:48	2.24	29.32
6:49	1.84	29.35
6:50	1.48	29.33
6:51	1.20	29.34
6:52	.96	29.32
6:53	.80	29.35
6:54	.68	29.38

give, at any time, the amount of heat produced into it since the beginning of the experiment. It follows from the table that the temperature of the slug would have increased 29.4°C during the experiment. If energy were produced uniformly throughout the pile the total amount of energy could be obtained by multiplying this temperature rise by the thermal capacity of all the metal in the pile. Since, however, more energy is produced in the center portion of the pile than on the outside a greater weight must be attributed to the metal placed near the center than to the metal placed at the periphery. Due to the somewhat irregular distribution of the metal in the pile the estimate of effective weight of metal present involves some uncertainty. Mr. Feld performed an approximate calculation with the result that the activity of the metal at the center of the pile is 2.50 times the activity of the metal at the edge of the pile. The slug on which the temperature measurement was performed was somewhat off the center of the pile and it was estimated that its activity was .784 times the activity of a slug placed at the center.

"It follows that the metal on which the measurement was performed was $.784 \times 2.50 = 1.96$ times more active than the average metal. The total amount of metal present in the pile was 3.04×10^7 gm. The total amount of energy produced in this metal is equivalent to that produced in $3.04 \times 10^7 / 1.96 = 1.55 \times 10^7$ grams of metal in which the energy was produced at the same rate as in the lump on which the measurements were taken.

"Therefore, the total amount of energy produced in the metal during the experiment was $.028 \times 1.55 \times 10^7 \times 29.4$ cal. (.028 is the specific heat of the metal). Two corrections must be applied to this result. One, to take into account the thermal capacity of the aluminum jacket which is ten percent of the capacity of the slug. The second correction must be applied to take into account the fact that a small fraction of the energy is produced in the graphite and not in the metal. Of the energy produced in the metal a small fraction representing the radioactive energy with a period of more than about half an hour is omitted after the completion of an experiment. In the calculation it was assumed that only ninety percent of the energy was recorded during the thermal experiment. Including these corrections the total amount of energy produced turns out to be 1.56×10^7 cal, equivalent to 13.1 kwh.

"From an integration of the readings on the galvanometer and on the Micromax during the radiation, it was found that the integrated reading of the galvanometer amounted to 1970 cm of deflection times hours, whereas the corresponding integral for the Micromax was .0277 deflection times hours. The deflection is read to be equal one at full scale of the instrument. From these data one obtains the following calibration of the two instruments.

"For the galvanometer - $1 \text{ cm deflection} = \frac{13.1}{1970} = .0092 \text{ kw,}$
and for the Micromax - $\text{full scale deflection} = \frac{13.1}{.0277} = 650 \text{ kw.}$

"It should be kept in mind, of course, that these calibrations are dependent on the position of the ionization chambers connected to the two instruments.

Since the experiment was performed the ionization chamber connected to the galvanometer has been moved from the position at which it was during the experiment, and consequently the corresponding calibration constant must be changed.

"The critical position of the control rod was measured before the experiment and found to be 98.06" at a pressure of 740.0 cm of Hg. During the experiment it was measured again at a time when the temperature was approximately constant. In the second measurement the critical position was found at 99.95" while the pressure was 740.1. This indicates that the pile is thermally stable with respect to a sudden rise of the temperature of the metal due to a reverse of the radiation. The activity of the pile decreases in this case by about .8 inhours per degree of temperature rise of the slug on which the measurement was performed."

The neutron flux at the center of the pile has been measured with Indium foils. Mr. Feld has calculated that the power of the whole pile, as determined from Fermi's experiment, bears the following relation to the neutron flux at the center. The central flux is 6.5×10^5 n/cm²/sec. This is in perfect agreement with the power calculated by means of the various constants of the pile.

A second temperature coefficient was measured by heating the pile with warm air. The air was carried through the structure by the ordinary cooling fans and the heat was supplied by steam radiators located in the air intake. The temperature rise of 14°C was obtained overnight. The displacement of the control rod was measured. Before the heating process was started the control rod was displaced from its critical position by an amount estimated to be the same as the displacement which would result from heating. From the period obtained the sensitivity of the control rod in this region was calculated. After the pile was heated the critical position was redetermined. The result of the experiment gave a temperature coefficient of .72 inhours per degree. This should be corrected for the change of the nitrogen density in the graphite due to the change of temperature. This should be 750/295 times the barometric coefficient. We have not yet determined the barometric coefficient on this pile with sufficient accuracy and will consequently use the Argonne value of .32 inhours per millimeter of mercury. This gives the temperature coefficient for the whole pile in vacuum of 1.4 inhours per degree. This figure may be revised following the determination of the barometric coefficient of this pile. The temperature coefficient for the heating of the metal alone may be approximated very roughly by the following considerations.

The coefficient for the particular slug studied was .8 inhours per degree. This should be changed to .6 inhours per degree for the temperature of the central lump. If we allow a factor of 2 to convert to the condition where all lumps are heated equally, this gives a temperature coefficient of 1.2 inhours per degree. This gives a qualitative result that the temperature coefficient of the graphite alone is not important. Since the coefficient of the metal is roughly equal to the coefficient of the whole pile. And, in fact, at atmospheric pressure a change in graphite temperature might actually give a positive temperature coefficient. This qualitative information is borne out qualitatively if we try to understand the changes in reactivity of the pile as it heats under its own power. These are not controlled experiments, but simply the result of observing temperature

and control rod positions during the start-up of the pile. If we ignore the temperature changes in the graphite and observe the change of critical position with the temperature of the #3 thermocouple, we obtain a temperature coefficient of .8 inhours per degree in agreement with Fermi's experiment. On the other hand, when the temperature of the metal is held constant while the temperature of the graphite is rising there is little change in the total reactivity of the pile.

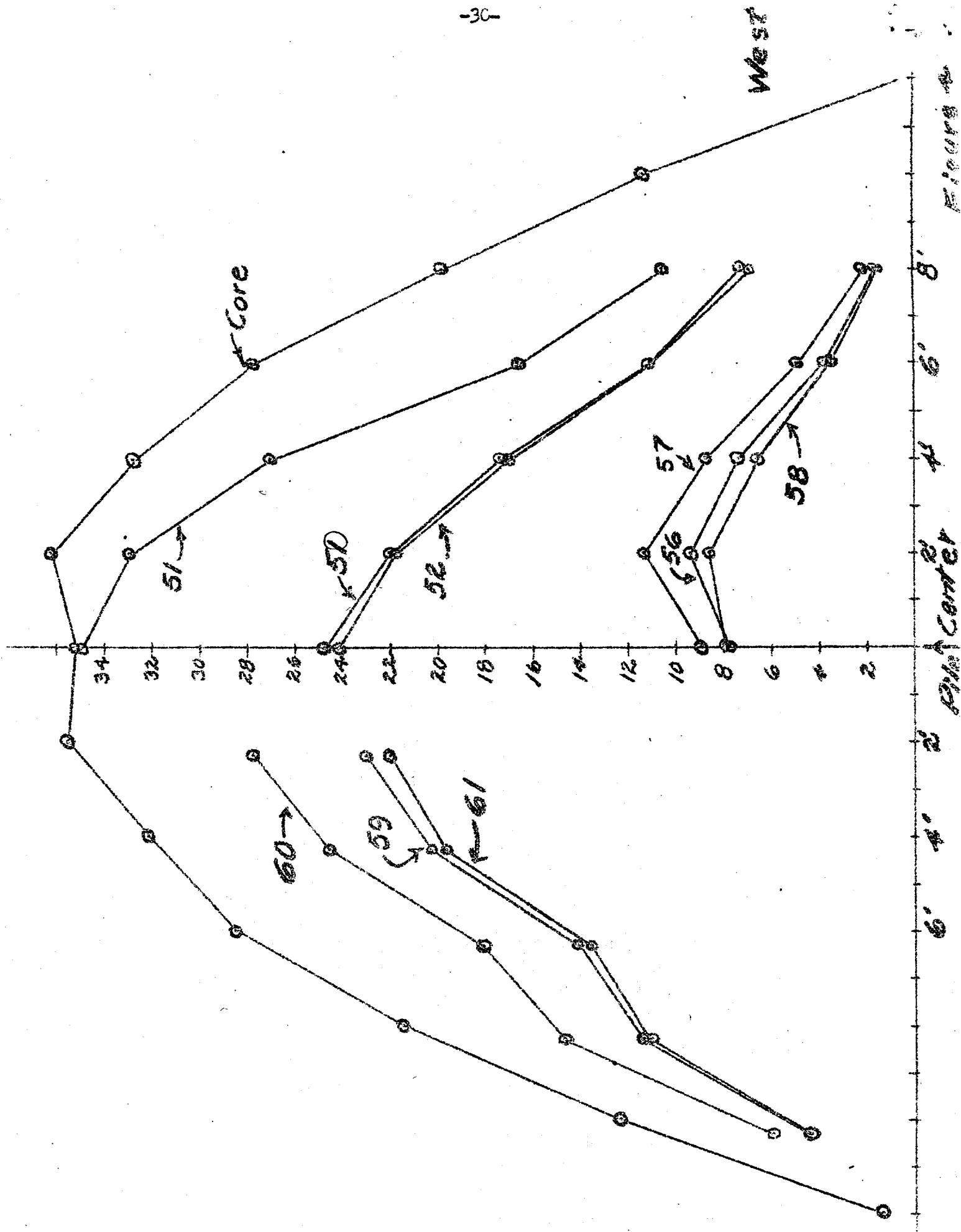
When the pile is run at high powers, that is 1500 to 2000 kw, the metal temperature changes very rapidly. Attempting to calculate the temperature coefficient from these observations has, in two cases, led to a coefficient of .4 inhours per degree as measured by the temperature of the same slug. This discrepancy is probably due to insufficient temperature data throughout the whole pile. Additional thermocouples are being installed to throw light on this point. Data on the distribution of neutron flux in the pile will also be helpful.

VII. Neutron Flux Measurements.

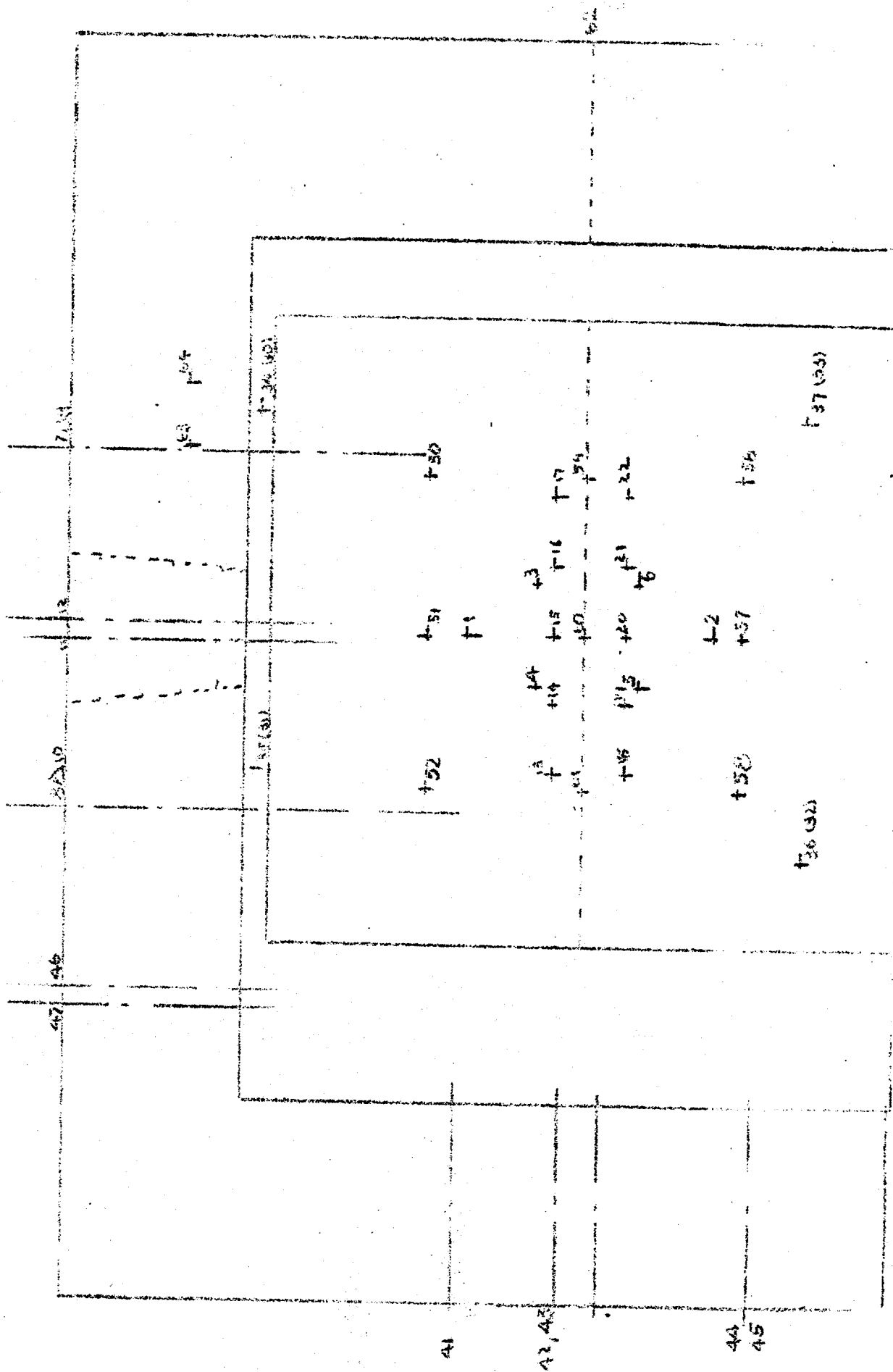
Preliminary data is now available on the distribution of neutron flux in the pile. Figure 4 shows the shape of these curves. This was taken with the pile operating steadily at about 450 kw. It was hoped to throw light on the temperature coefficient by studying the change of this distribution of temperature. However, sufficiently accurate data have not been obtained.

The drawing shows the distributions in the various slot holes in which foil measurements may be made. The curve marked "core" was measured in a slot which ran parallel to the direction of the uranium rods about one inch under the metal in hole 1868. The other slots run into the pile at right angles to the direction of the channels. Holes 59, 60, and 61 are at the same height as the core slot. Hole 59 is six feet closer to the charging face of the pile than hole 60, and hole 61 is six feet toward the discharge face. Holes 50, 51, and 52 are six feet above; and holes 56, 57, and 58 are six feet below 59, 60, and 61.

The arrangement may be seen on Figure 5. No attempt has been made to fit these measurements with theoretical calculations for the distribution in the unsymmetrically loaded pile.



View of Pile from Experimental Face



VIII. Stack Gas Activity
(W. R. Kanne, M. Wilkening)

The pile stack gas activity has been detected by both an ion chamber and a Geiger counter. The sampled gas flows through the ion chamber and around the Geiger counter contained in a small housing. The flow through this system is obtained by short circuiting the fans.

The chamber used in the 115 annex were calibrated at Chicago by irradiating a sample of pure argon with cyclotron slow neutrons. This gas was admitted to the chamber and its decay was followed with a calibrated Beckman microammeter. The direct result of this calibration is that the nvt to which normal air is subject is 1.3×10^{20} times the ionization current in amperes collected by the chamber. This result does not involve the use of a cross section, but it assumes that argon is the only substance activated. If the argon cross section is assumed to be 1×10^{-24} cm² one can arrive at the result that 10-12 curies of activated argon per cc give 1.28×10^{-11} ampere.

A number of decay curves have been run on pile air samples and half lives of 110 to 115 minutes have been obtained, without any indication of appreciable short or long lived activity. The half life obtained indicates argon 41.

There is, however, a discrepancy between the activity indicated by the ion chamber with pile air flowing through it and that to be expected on the basis of the above calibration and power calibration of the pile. When operating at 500 kw with an air flow of about 50,000 cfm 7×10^{-10} amp is observed while reasonable assumptions about the nvt would indicate that about 2×10^{-10} amp should be observed.

The calibration indicates that under the above operating conditions there are 5.5×10^{-11} curies per cc in the gas. Parker has given 4×10^{-12} curies per cc as the 8 hour tolerance concentration for an infinite hemisphere of this gas.

The gas is then considerably above this tolerance. However, the conditions implied in this tolerance are fortunately not ordinarily satisfied. If these calibrations are correct it would nevertheless be possible to approach radiation tolerances. An amount of gas to give an effectively infinite hemisphere is discharged from the stack in one to two half lives of the argon. If an unusually long "perfect" inversion should occur it is conceivable that radiation tolerances might be approached. The temperature of the gas discharged from the stack is above that of the outside air, at worst mixing is still considerable, and inversions are apparently usually of short duration in comparison to the time required to discharge a volume of gas equivalent to an effectively infinite hemisphere. The stack gas should not be considered a hazard at the present time. It may be of interest that Parker has observed "detectable" quantities of radiation due to the stack gas.

It has been noticed that the stack activity increases markedly if the fans are stopped shortly after the pile is stopped. This is probably due to the delayed neutron intensity which causes the irradiation of air which circulates through the pile due to the natural stack draft. The air is thus exposed for a very long time to the weak intensity. The fans were recently stopped five minutes after the pile was stopped, when the galvanometer still indicated 0.5 μ ev. The chamber gradually built up activity which would have reached a maximum of about 20×10^{-11} curies per cc. The chamber was closed and a decay of 115 minute half life was observed, indicating that the activity is due to argon. It is also possible that intensely activated argon could diffuse out of the graphite but the marked dependence of the intensity observed on the delay between stopping the pile and the fans seems to indicate that the delayed neutrons probably cause the effect.

The air filter was recently checked for accumulated activity with a negative result. The filter has now been removed so that the maximum effect can be obtained from any jacket failure.

It may also be of interest that about 29 cubic feet of the stack gas in the ion chamber give only a minute reading on a Lauritsen electroscope at the outside of the chamber.

Dissolver off-gas
(W. R. Kanne, G. Branch)

Xenon activity has been detected in the semi-works dissolver off-gas with both a stainless steel and a glass Geiger counter. The decay periods obtained with a counting rate meter are unfortunately not reliable enough to determine the amount of iodine in the off-gas. However, there is a qualitative result that activity in addition to that due to Xenon comes off since metal that had a cooling period of about a month gas off gas with a decay half life of more than five days, while metal with a twelve day cooling period gave off gas with a decay half life of less than five days.

Most of the equipment to be used in Building 204 for the monitoring of the 205 off gas and the stack activity has been tested and is ready for installation pending the completion of construction.